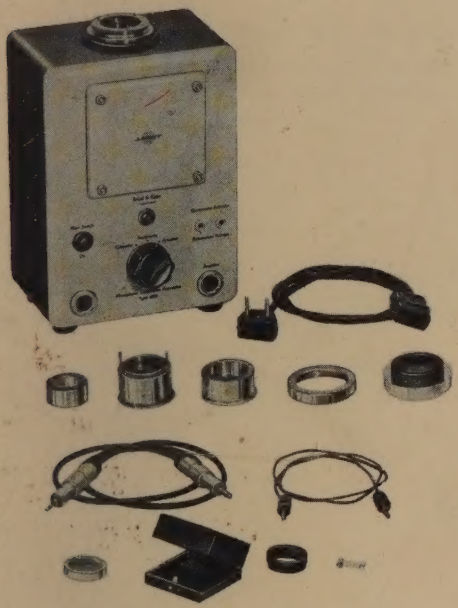
4120

INSTRUCTIONS AND APPLICATIONS

Microphone Calibration Apparatus

Type 4120



Equipment for the Absolute Sensitivity Calibration of Condenser Microphones by the Reciprocity Method plus the Electrostatic Actuator method. For use with the Automatic Frequency Response Recorder type 2310

Beat frequency oscillators
Low frequency oscillators
Deviation test bridges
Strain gauge apparatus
Frequency measuring bridges
Distortion measuring bridges
Heterodyne voltmeters
Audio frequency spectrometers
Frequency analyzers
Level recorders, a. c. and d. c.

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BRÜEL & KJÆR

Nærum, Denmark . Phone Nærum 500 . Telegrams: BRUKJA, Copenhagen

MICROPHONE CALIBRATION APPARATUS TYPE 4120

This apparatus is constructed in the first place for the precision calibration of Brüel & Kjær's Condenser Microphone type 4111, and of the cartridges in the Artificial Ears types 4107 and 4109, as well as the regulating microphone in the Artificial Voice type 4210

The condenser microphone's absolute sensitivity can be found with this calibration apparatus according to the reciprocity method, and, further, the frequency characteristics can be found with the electrostatic actuator.

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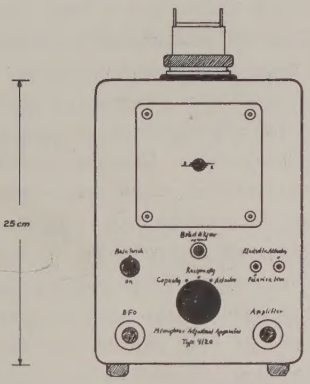


Fig. 1. Front Plate of Apparatus with Dimensions.

The pressure response, that is to say the absolute sensitivity, is measured by a socalled reciprocity method. This method is easy to carry out with very great accuracy over the frequency range 80-5000 c/s. In principle, the method could quite well be used over a greater frequency range, for example from 20 c/s to 14000 c/s, but

the difficulties would then increase within the lower end of the range because of small leaks causing trouble, and at the top of the range because the wave length would become small in relation to the dimensions of the coupler, whereby faults would arisé on account of the wave motion in it. These latter faults could be avoided by choosing smaller couplers at higher frequencies and filling them with hydrogen to make the wave length greater. If these artifices are introduced, the precision of the measurements will not only be considerably reduced but unfortunately they will also become very difficult to carry out.

For this reason it has been decided to use the reciprocity method here only within a narrow frequency range, so that the absolute sensitivity can be measured with the greatest degree of precision, and thereafter calculate the frequency characteristic, i.e. the pressure response as a function of the frequency, with the help of an electrostatic actuator.

The electrostatic actuator consists of an electrically insulated grid brought in the immediate vicinity of the condenser microphone's diaphragm. A high polarization voltage is applied between the diaphragm and the grid, and superimposed on this an alternating voltage of any desired audio-frequency. Because of the electrostatic attraction the grid will set the diaphragm in motion corresponding to that motion that would be produced in it by a sound pressure. The electrostatic attraction is proportional to both the polarization and the alternating voltages and inversely proportional to the square of the distance between the grid and the diaphragm. This method can in principle be used satisfactorily for absolute measurements, but it suffers from the difficulty that it is difficult to judge the small distance between the grid and diaphragm precisely, and as this distance furthermore appears in the formulae in the second power, the uncertainty of the measurement is as a rule $\pm$ 1 to 1.5 db. Another disadvantage is that the high polarization voltage between the diaphragm and the grid pulls the diaphragm a little out of its normal position, so that a fault in the sensitivity can easily arise.

Calibration Apparatus type 4120 consists, as is seen in figs. 1 and 2, of a main unit, which is fitted at the top with a base piece

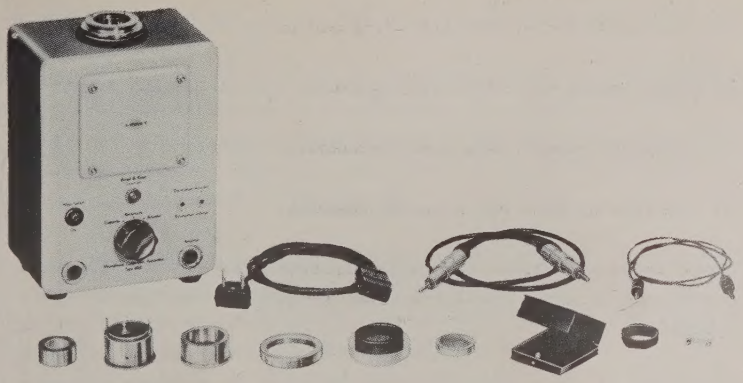


Fig. 2. Photograph of the Calibration Apparatus with accessories. 1). Microphone Cartridge. 2). A.S.A.Coupler with tube for hydrogen filling. 3). 3 cm^3 Coupler. 4). Locking ring. 5). Electrostatic actuator. 6). Power cable. 7). Screened cable. 8). Connecting lead for actuator or polarization voltage. 9). Case for microphone cartridge. 11). Insulating ring. 12). Coupling contact.

for a microphone cartridge. Various types of couplers can be mounted above this cartridge in order to couple another condenser microphone to the microphone cartridge in 4120. The accessories normally delivered are:

1) Microphone cartridge and protective grid in a case. This microphone cartridge has a linear free field characteristic and can, therefore, besides being used for calibration, be used as a spare cartridge for the normal condenser microphone 4111.

2) A 19.5 cm^3 coupler of the type recommended by the American Standards Association Z 24.4 "Pressure Calibration of Laboratory Standard Pressure Microphones". Cavity 43 x 12.4 mm. This coupler is constructed for filling with hydrogen.

3) A 2.96 cm^3 coupler for normal practical laboratory use. Cavity 26 x 5.2 mm. The coupler is not constructed for filling with hydrogen.

4) Locking ring for couplers.

5) Electrostatic actuator fitting condenser microphone 4111.

6) Mains cable and screened cable with coaxial plugs.

7) Connecting cable for electrostatic actuator.

8) Insulating ring and coupling contact.

These items are stored in a space in the upper part of the calibrating apparatus. There are also instructions for use of the apparatus.

Definitions

The American Standards Association use the following definitions:

Open-Circuit Voltage. The root-mean-square (rms) open-circuit voltage of a microphone at a given single frequency is the voltage appearing at its terminals when the microphone is working into an effectively infinite electrical impedance.

Pressure Response. The pressure response of a microphone at a given single frequency is 20 times the logarithm to the base 10 of the ratio of rms, open-circuit voltage, to the rms sound pressure when the sound pressure is uniformly applied over the surface of the pressure-sensitive element (diaphragm).
The ratio of the open-circuit voltage to the sound pressure causing it is generally a complex number. The pressure response is 20 times the logarithm to the base 10 of the absolute value of this complex ratio. Cgs unit: db relative to 1.00 volt $dyne^{-1}$ cm^2 (volt $microbar^{-1}$)

Pressure-Response Phase Angle. The pressure-response phase angle of a microphone at a given single frequency is the phase angle between the open-circuit voltage and the sound pressure uniformly applied over the surface of the pressure-sensitive element (diaphragm).
Unit: Degrees.

Free Field. A free field is a field (wave or potential) in a homogeneous, isotropic medium free from boundaries. In practice it is

a field in which the effects of the boundaries are negligible over the region of interest.

Note: The actual pressure impinging on an object (e.g., electroacoustic transducer) placed in an otherwise free sound field will differ from the pressure which would exist at that point with the object removed, unless the acoustical impedance of the object matches the acoustical impedance of the medium.

Free-Field Voltage Response. The free-field voltage response of an electroacoustical transducer used for sound reception is the ratio of the voltage appearing at the output terminals of the transducer when the output terminals are open-circuited to the free-field sound pressure existing at the transducer location prior to the introduction of the transducer in the sound field.

The free-field voltage response is usually expressed in decibels, viz. 20 times the logarithm to the base 10 of the quotient of the observed ratio divided by the reference ratio, usually 1 volt per microbar. The free-field response is defined for a plane progressive sound wave whose direction of propagation has a specified orientation with respect to the principal axis of the transducer.

Cgs unit: db relative to 1.00 volt dyne^{-1} cm^2 (volt microbar^{-1})

Acoustical Impedance of a Microphone. The acoustical impedance of a microphone at a given single frequency is the complex ratio of the sound pressure uniformly applied over the surface of the pressure-sensitive element (diaphragm) to the volume velocity.
Units: Acoustical ohm (dyne sec cm^{-5})

Equivalent Volume of a Microphone. In dealing with closed cavity measurements (coupler measurements), it is convenient to express the acoustical input impedance of a microphone of the type described in terms of the acoustical impedance of an equivalent volume V_e of a gas enclosed in a rigid cavity by use of the following relation

$$V_e = \frac{\gamma P}{j\omega Z_a}$$

where

		Cgs System
γ	= ration of specific heats	number
P	= ambient pressure	dyne cm^{-2}
Z_a	= acoustical impedance of the microphone	dyne sec cm^{-5}

Reversible Microphone. Consider a linear, passive, electroacoustical transducer. Let p = pressure applied to the diaphragm and E = voltage applied to the electric terminals. Both p and E are sinusoidal and of the same frequency. Let u = diaphragm volume velocity, and i = current through the electric terminals. The equations of the transducer are

$$z_{11}i + z_{12}u = E$$
$$z_{21}i + z_{22}u = p$$

where z_{22} is the acoustical impedance looking into the transducer when the electric terminals are open, and z_{11} is the electrical impedance looking into the transducer when the mechanical motion is stopped (diaphragm blocked). The transducer is said to be reversible if the transduction coefficients z_{12} and z_{21}, when expressed in a consistent system of units, are such that $|z_{12}| = |z_{21}|$.

For practical work with condenser microphones of the type 4111 which are constructed with a cathode-follower, it is more convenient simply to use the output voltage from the cathode-follower in the definitions instead of using the open-circuit voltage from the cartridge, as prescribed by the definitions. By using the actual output voltage all later corrections for the cathode-follower's attenuation and input capacity are avoided. The definitions for the pressure response and free-field response will then be:

The pressure response M of a condenser microphone at a single frequency is the ratio of the output voltage from the cathode-follower to the sound pressure when the sound pressure is uniformly applied over the diaphragm. The values are given in decibels re 1 volt/μbar or in millivolts per μbar. 1 μbar = 1 dyne/cm^2. Both sound pres-

sure and voltage have to be measured either as r.m.s., average or peak values. The free-field response of a condenser microphone at a given single frequency is the ratio of the output voltage from the cathode-follower to the free-field sound pressure existing at the microphone location with the microphone removed from the sound field. The microphone must be placed with its diaphragm perpendicular to the sound source. Values in decibels re 1 volt/μbar or mV/μbar.

For every microphone type there is a unique correspondence between pressure response and free-field response, the difference depending only on the microphone's ability to reflect sound waves. This characteristic is dependent on the microphone's dimensions and the wave length of the sound. It is thus possible once and for all to establish, both by calculation and measurement, the difference between pressure response and free-field response, and therefore when one is known it is possible immediately to arrive at the other. With microphone calibrations it is simpler to carry out pressure calibration, therefore only pressure calibration will be discussed in what follows. The free-field is easily found by calculation. Fig.3 shows the correction curve for the B & K microphone type 4111 as a function of frequency.

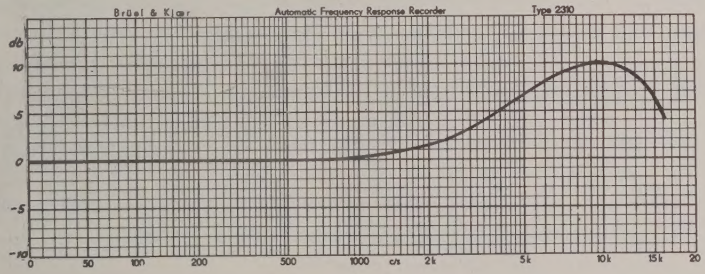


Fig. 3. Conversion curve showing free field response minus pressure response for Condenser Microphone type 4111.

Short Theory of Reciprocity Calibration

In the reciprocity method two microphones 1 and 2 are used, and the method in brief consists in coupling the two microphones together acoustically, using the one as a transmitter and the other as a re-

ceiver, thereby finding the product of the absolute sensitivity of the two microphones $M_1 M_2$, and by comparison of the two microphones 1 and 2 in one and the same sound field finding the ratio between the microphones' sensitivity $\frac{M_1}{M_2}$. The absolute sensitivity of the individual microphones can thereafter easily be calculated from the two equations with two unknowns.

In order to show how the condenser microphones can be calibrated by the application of the reciprocity theorem it is necessary to consider fig. 4, where two microphones are coupled by a closed rigid cavity of known physical dimensions. The cavity is filled with a gas having a known ratio of specific heats

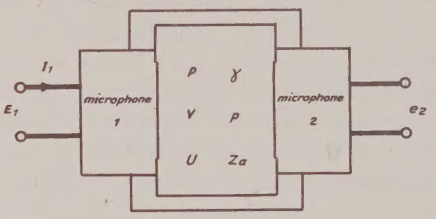


Fig. 4. Electro-acoustic Network for Reciprocity Calibration.

The following symbols are used.

P = ambient air pressure measured in μbars (1 atmosphere = 1.01 x 10^6 μbar).

γ = ratio of the specific heats of the gas in the cavity (with dry air γ = 1.402 and for hydrogen γ = 1.408 at 25°C).

V = volume of cavity measured in cm^3.

p = r.m.s. sound pressure measured in μbar.

U = r.m.s. volume velocity measured in cm^3/sec.

Z_a = impedance of cavity = $\frac{\gamma P}{j\omega V}$ measured in acoustic ohms = g $sec^{-1} cm^{-4}$.

ω = angular velocity = $2\pi f$

A sinusoidal voltage E_1 (r.m.s. value) of frequency f is impressed on a transducer 1. A sound pressure p is produced in the cavity where

$$p = U Z_a = \frac{\gamma PU}{j\omega V} \qquad (1)$$

If all the cavity walls were rigid, their acoustic impedance would be very large compared to that of the volume of gas in the cavity. However, the microphone diaphragms have a small influence on the impedance of the cavity. The condenser microphone type 4111 has a diaphragm movement corresponding to the compression of an air volume of 0.1 cm^3. This volume is called the Equivalent Volume of a microphone. The volume of the cavity V is defined as the real volume plus twice the equivalent volume of the microphone.

By definition the pressure response of microphone 2 is

$$M_2 = \frac{e_2}{p} \text{ volts per } \mu\text{bar}$$

therefore

$$e_2 = M_2 \frac{\gamma PU}{j\omega V} \qquad (2)$$

The reciprocity theorem can be expressed as follows:

In a passive linear reversible microphone, the ratio of input current I_1 to the volume velocity U in the cavity, when the microphone is used as sound source, is equal to the ratio of the sound pressure p actuating the diaphragm to the open-circuit voltage e developed across the electrical terminals of the microphone, when the microphone is used as a microphone.
That is to say

$$\frac{I_1}{U} = \frac{p}{e} \times 10^{-7} = \frac{p\ 10^{-7}}{1.06 e_1} = \frac{10^{-7}}{1.06 M_1} \qquad (3)$$

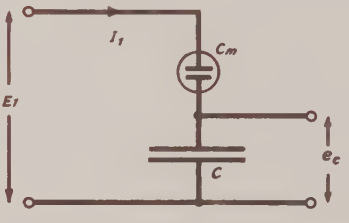
The conversion factor 10^{-7} is used here because p and U are in c.g.s. units, while I_1, e and e_1 are measured in practical electrical units.

The factor 1.06 is a correction for the attenuation in the cathode-follower.

From (2) and (3) an expression is obtained for the product of the two microphones' pressure responses

$$e_2 = M_1 M_2 \frac{\gamma P \times 10^7 \times I_1 \times 1.06}{j\omega V} \qquad (4)$$

The only problem is that it is difficult to measure I_1 precisely. By connecting the transmitter microphone, as shown in fig. 5, in series with a known capacity C which is great in comparison with the condenser microphone's capacity C_m, and measuring the voltage drop e_c over C with the same input voltage E_1 on the transmitter microphone, I_1 can be calculated from



$$I_1 = j\omega C \times e_c \qquad (5)$$

which placed in (4) gives

$$\frac{e_2}{e_c} = M_1 M_2 \frac{\gamma P \times 10^7 \times C \times 1.06}{V} \qquad (6)$$

Fig. 5. Principle for the measurement of current I_1 through the transducer microphone.

The normal pressure response of the condenser microphone type 4111 is approximately 50 db below 1 volt per μbar. It is then convenient to choose the ratio $\frac{C\gamma P}{V}$ so that $e_2 = e_c$ when both the microphones have a pressure response of exactly - 50 db. This very convenient method is first described by Dr. A.Kerbye Nielsen: "A Simplified Technique For the Pressure Calibration of Condenser Microphones by the Reciprocity Method", ACUSTICA vol. II, p. 112, 1952. That is to say

$$106\ C = \frac{V}{\gamma P}$$

where C is measured in farads and $\frac{V}{\gamma P}$ in c.g.s. units.

With the ASA standard coupler of 19.5 cm^3 the corresponding value of C = 0.130 μF and with the small coupler of 2.95 cm^3 the corres-

ponding value of C = 19.8 nF. In the Microphone Calibration Apparatus type 4120 the built-in condenser C = 19.8 nF and by using the small coupler the voltages e_2 and e_c are compared. If they are equal, the average response of the microphones is -50 db. If e_2 is found to be n db below e_c, the average response of the microphones will be $-50-\frac{n}{2}$ db re 1 volt/μbar.

If the ASA coupler is used and the condenser C = 19.8 nF, the response of the two microphones is -41.8 db re 1 volt per μbar when $e_c = e_2$.

The ratio of the sensitivities of the two microphones 1 and 2 is found by using a third microphone as transducer and with successive measurements comparing 1 and 2. If microphone 1 is found to be m db more sensitive than microphone 2, the pressure responses are

Microphone 1 = $M_1 = -50-\frac{n}{2}+\frac{m}{2}$ db re 1 volt per μbar

and Microphone 2 = $M_2 = -50-\frac{n}{2}-\frac{m}{2}$ db re 1 volt per μbar.

Electrostatic Actuator

At higher frequencies, pressure calibration of condenser microphones using a coupler and the reciprocity technique is not feasible because of wave motion in the cavity. For recording the frequency response the electrostatic actuator is nearly ideal.

The electrostatic actuator consists of a fixed slotted plate mounted very near to the diaphragm of the microphone. An alternating plus a steady potential is applied between the slotted plate and the diaphragm. See fig. 6 left. The electrostatic attractive force F between two plates with an area S, brought parallel to each other at a distance d, is, as is known from electrostatics,

$$F = \frac{E_s^2 S}{8\pi d^2} \text{ dyn}$$

where E_s is the electrical potential difference between the plates measured in electrostatic volts. All lengths and areas are given in cm.

By equating this force with a sound pressure we find

$$p = \frac{E^2}{8\pi d^2 \times 9 \times 10^4} \text{ dyn/cm}^2$$

where E is now given in practical volts. The voltage E is, as shown in the set-up in fig. 6, a combination of the polarization potential E_o (approx. 750 volts) and a lesser alternating potential e $\sin\omega t$ of a value of 10-20 volts. $\omega = 2\pi f$ = angular frequency. The resulting voltage is therefore

$$E^2 = (E_o + e \sin\omega t)^2 = E_o^2 + 2E_o e \sin\omega t + e^2 \sin^2\omega t.$$

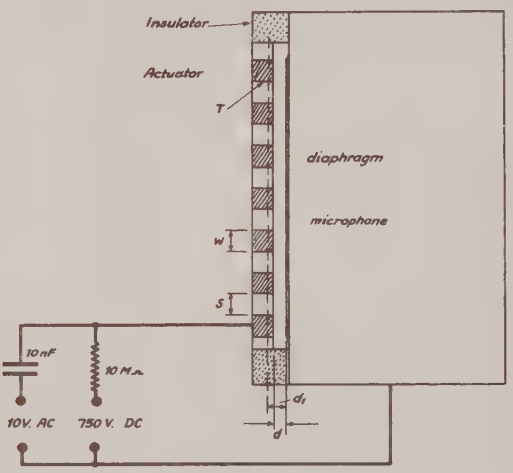


Fig. 6. Principle of the Electrostatic Actuator.

The first term gives a constant attraction between the diaphragm and the actuator, which attempts to attract the diaphragm away from the back electrode, thus reducing the microphone's capacity. At 750 volts the capacity of 4111 is only reduced 3-4%, so this attraction has no significance for the frequency characteristic and only a slight significance for the absolute sensitivity. The second and most important term affects the membrane with an oscillatory pressure whose frequency is that imposed.

The third term affects the diaphragm with the double frequency, as

$$e^2 \sin^2 \omega t = \frac{e_2}{2} (1 - \cos 2\omega t)$$

thus giving rise to a distortion of the voltage produced by the microphone equal to

$$\frac{e^2}{2 \times 2E_o} e = 4\frac{e}{E_o}$$

It will be seen from this that if one wishes to keep distortion to less than for example 2% the ratio E/e should not be less than approx. 12. Here e is the peak value of the audio frequency voltage.

We can calculate from the second term the alternating pressure on the diaphragm

$$p = \frac{8.85\ E_o e}{10^7 d_1^2} \quad \text{dyn/cm}^2 = \mu\text{bar}$$

In this formula we can either insert the peak values for the sound pressure p and audio frequency voltage e or r.m.s. values for p and e. In actual practice the distance d must be modified to take into account the slots in the actuator. These slots are introduced to minimize the acoustic loading on the microphone diaphragm. In fig. 6 the grill sections have a width W and the slots a width S and a depth T, and it is theoretically permissible, speaking electrically, to replace the grill by a solid plate with a new effective spacing d_1. For a grill of the type shown, the ratio d_1/d has been computed for various values of W, S, and d. The formula is

$$d_1 = \frac{d}{\sqrt{K}} \quad \text{where} \quad K = 1 - \frac{2 \operatorname{arctg} \frac{S}{2d}}{\pi \left(1 + \frac{W}{S}\right)} .$$

The distance d is measured by first measuring the thickness T with a micrometer screw and then with a measuring microscope estimating the distance from the diaphragm to the surface of the grating.

However, this measurement is uncertain, so the absolute exactness obtained is seldom better than $\pm$ 1.5 db. Therefore the electrostatic actuator should only be used for frequency characteristics and the reciprocity method should be used for the measurement of absolute sensitivity in a narrower frequency range.

Description and Operation of Type 4120

The apparatus consists of a transducer cartridge which, when the main switch is in position "Reciprocity", is supplied with an AF-voltage from a B.F.O. at the screened socket marked "B.F.O." The necessary polarization voltage is supplied from outside at the banana-pin socket marked "Polarization". Normally this polarization voltage is taken from the microphone amplifier 2601 or the analyser 2105 used as amplifier for the microphone to be measured. In this way all the cartridges are ensured the same polarization voltage, and one avoids corrections for differences in polarization voltage between the transmitter and receiver cartridge.

When the main switch is in position "Capacity" the current I_1 through the transducer cartridge is measured by measuring the voltage drop e_c across the condenser C. The size of this condenser is adjusted in relation to that of the small coupler, so that when the voltage drop over C is equal to the output voltage from the receiver microphone the average sensitivity of the two microphones is exactly -50 db re 1 volt/μbar. When the main switch is in the position marked "Actuator" the B.F.O. will be coupled to the socket marked "Electrostatic Actuator", which at the same time will be fed with a high polarization voltage of approx. 750 volts. The Electrostatic Actuator is placed on the microphone one wishes to measure and is connected by a single cable to the banana-pin socket " Electrostatic Actuator". The high polarization voltage is powerfully stabilized, so that if on a later occasion a previously measured microphone needs to be checked, it is only necessary to carry out a single grating measurement in order to control the original complete measurement. N.B. The power supply to the Calibration Apparatus should only be on when the Electrostatic Actuator is being used.

Recording of Frequency Response of Condenser Microphones

The Electrostatic Actuator is placed on the Condenser Microphone and connected to the Calibration Apparatus as shown on fig. 7,

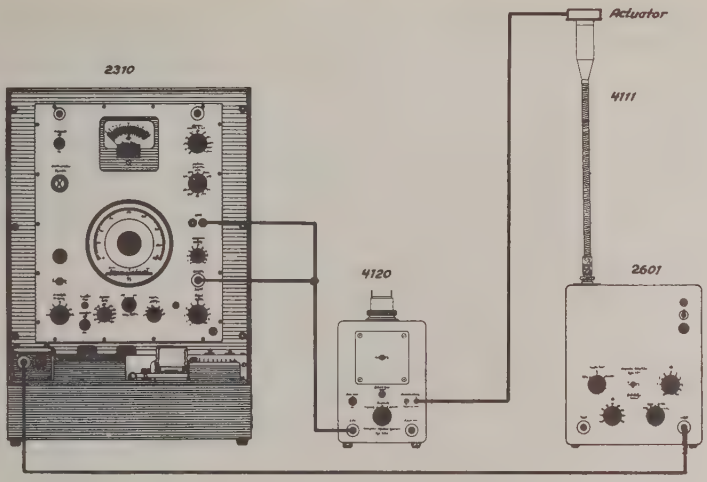


Fig. 7. Recording of a microphone's pressure-frequency characteristic with the electrostatic actuator. Power on 4120.

where the Automatic Frequency Response Recorder type 2310 is used together with Microphone Amplifier type 2601. The Calibration Apparatus 4120 is connected to the power supply, the apparatus is switched on and the main switch is placed in position "Electrostatic Actuator". The measurements should be carried out in a comparatively quiet room. The actuator rests on the microphone merely with its own weight, and one must make sure that the surface of the microphone is free from dirt and dust, which, if lying on the surface of the diaphragm, can give rise to noise, and if on the edge will give a wrong grating distance. The value of the AF-voltage should be chosen between 10 and 20 volts (maximum 24 volts). In order to hold the voltage quite constant over the whole frequency range the compressor input to the B.F.O. should be connected to the output socket. The B.F.O.'s volume control is turned up to maximum and the output voltage controlled by means of the compressor volume control. Before recording the microphone's frequency characteristic a control check can be made by recording the frequency characteristic of the microphone amplifier, B.F.O. and Recorder. Fig. 8 shows examples of the frequency characteristics of two condenser microphones. As one is usually interested in know-

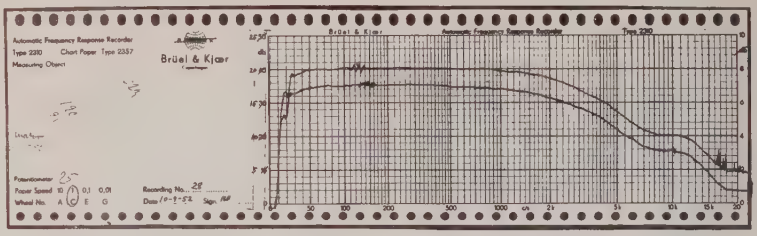

Automatic Frequency Response Recorder
Type 2310 Chart Paper Type 2337
Measuring Object
Brüel & Kjær
Brüel & Kjær Automatic Frequency Response Recorder Type 2310

Fig. 8. Pressure-frequency characteristics of two microphones, No.'s F.190 and F.191. Polarization voltage: 750 V. A.F. voltage: 25 V_{eff}.

ing the microphones' free-field characteristic the curves shown in fig. 8 must be recalculated with the help of the conversion curve shown in fig. 3. If many microphones have to be measured, this work of calculation is rather great, and one can therefore insert a filter as shown in fig. 9 between the B.F.O. and the cali-

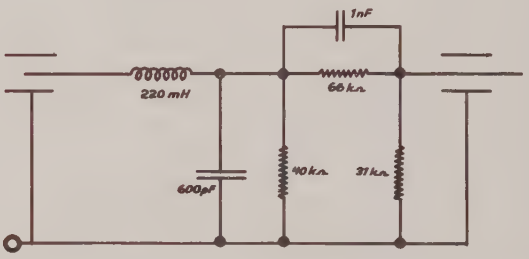


Fig. 9. Filter for insertion between Beat Frequency Oscillator and Calibration Apparatus to compensate for the difference between pressure and free-field characteristics.

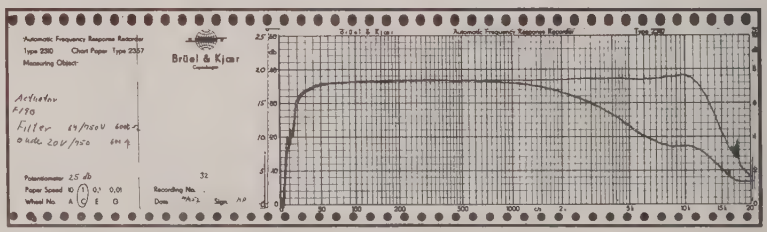


Fig. 10. Free-field frequency characteristic for condenser microphone recorded with the help of the filter, and pressure frequency characteristic recorded with actuator without filter.

bration apparatus and in this way carry out the conversion electrically, so that one can record directly the microphones' free-field frequency characteristic. Fig. 10 shows a set of curves from the same microphones as shown in fig. 8 recorded with the correction filter shown in fig. 9.

Absolute Sensitivity Estimate by the Reciprocity Method

For these measurements it is not essential to have a recorder, but it is a great help to make use of the Automatic Frequency Recorder type 2310 and Microphone Amplifier type 2601. To carry out the reciprocity method two condenser microphones are necessary.

Comparison of the two Microphones.

The cartridge belonging to 4120 should be attached. Both the large and the small couplers can be used. Make sure that the coupler fits tightly over the cartridge. Usually a little vaseline can be used to make it fit tightly. The calibration apparatus is connected as shown in fig. 11, and the main switch turned to "Reciprocity".

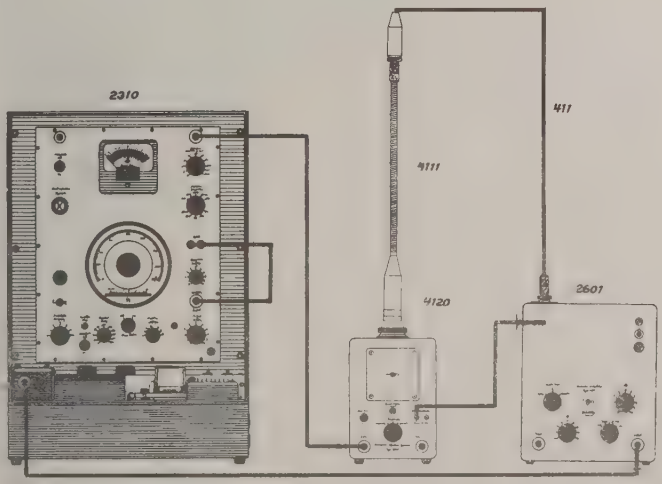


Fig. 11. Comparison of two microphones' sensitivities. Power cable to 4120 must be disconnected.

The condenser microphone is fitted vertically above 4120 and connected to the microphone amplifier by the extension piece type 4115. The AF-voltage from the B.F.O. is chosen as approx. 10 V, and the compressor can also be used with advantage here to keep the voltage constant. The polarization voltage to the transmitting cartridge is taken directly from the microphone amplifier by connecting the socket marked "Polarization" on the calibration apparatus with the socket marked "Polarization Voltage" on the microphone amplifier. This socket is only found on microphone amplifiers with a series number from 5253. On earlier models the microphone amplifier's backplate must be removed and a connection made to the stabilizer tube. Fig. 12 shows some examples of the comparison curves of two microphones, where the first microphone is measured and then immediately afterwards the second. As it is

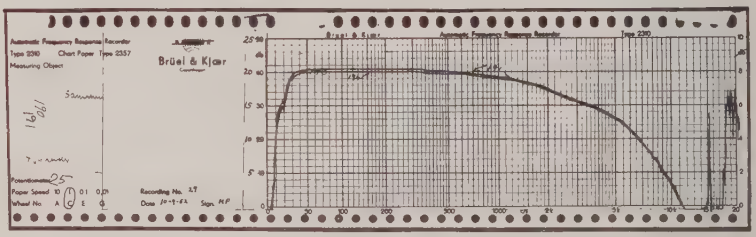


Fig. 12. Recording of comparison of two type 4111 microphones No.'s F190 and F191, recorded with 25 db potentiometer.

necessary to obtain as great an accuracy as possible, it is an advantage to choose a potentiometer on the Level Recorder with a small range, for example 10 or 25 db. As can be seen it is a great advantage to be able to record the two microphone curves on the same diagram, whereby comparison is made very much easier.

Estimation of Two Microphones' Average Response.

The one microphone cartridge is used as a transmitter and is fastened in the calibration apparatus. The connections are still as shown in fig. 11. As a rule a 25 db potentiometer is used and the level adjusted so that there is room on the paper to record the subsequent current measurement. With the normal condenser

microphone having a sensitivity of -50 to -56 db re 1 volt/μbar and with the small coupler, there should be place for a 10 db rise in level. If the ASA coupler is used, a 50 db potentiometer must be used, as there will have to be room for a rise in level of about 30 db above the e_2 curve.

The current I_1 through the transmitting cartridge is calculated by means of the set-up shown in fig. 13. The connection between the microphone and the microphone amplifier is broken. The cali-

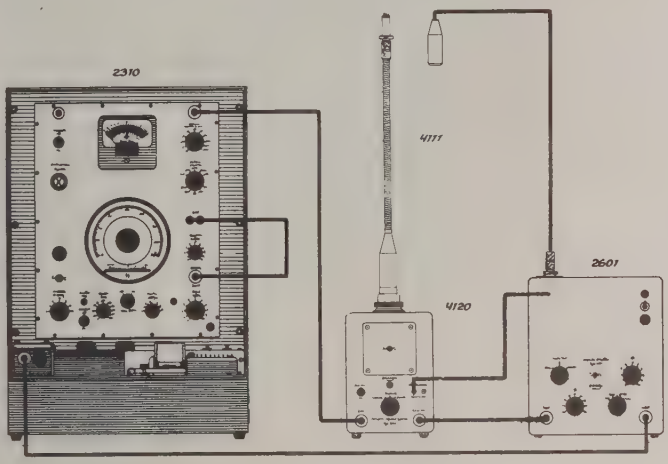


Fig. 13. Set-up for the estimation of the current through the transmitting cartridge. Power cable to 4120 must be disconnected.

bration apparatus is set to "Capacity", and "Amplifier" is connected by a screened cable to the input voltage socket of the microphone amplifier. The microphone amplifier is set to "Input". The adjustments on 2310 and the amplification of the microphone amplifier must not be changed. Then on the same paper as before the voltage e_c is recorded, being proportional to the current I_1. I_1 is only very slightly dependent on frequency, as will be seen from fig. 14, where the relationship between e_c and e_2 is shown. It is recommended as a control to repeat the measurement with exchanged microphones. Both e_c and e_2 should be measured, and the

same relationship between e_c and e_2 should be found, as this relationship (the difference expressed in db) determines the average sensitivity of the two microphones.

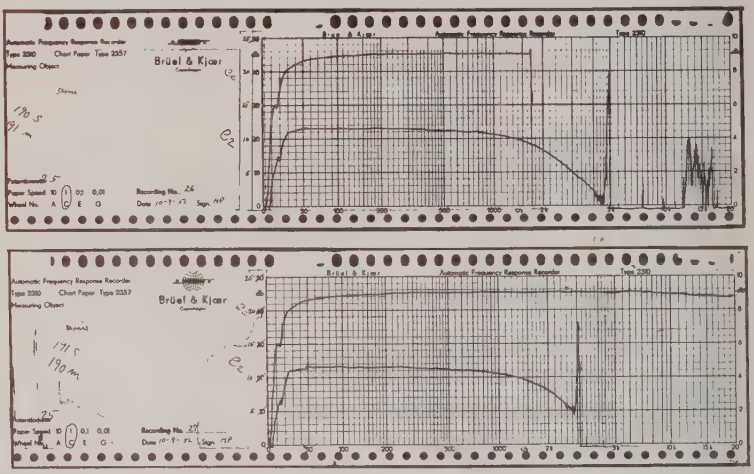


Fig. 14. Relationship between current through transmitting cartridge e_c and the voltage e_2 produced, for two microphones. Above, No.190 used as transmitter and No.191 used as receiver. Below, the transmitting and receiving microphones are exchanged.

Important: When a cartridge is inserted in a coupler this should be done slowly and carefully. Be careful not to knock the diaphragm or by rapid insertion or removal of the coupler expose the diaphragm to too great an air pressure. After insertion let the cartridge and coupler reach the same temperature and allow time for any possible air pressure difference in the coupler and the cartridge to equalize. Pressure equalization in the large coupler takes place through the capillary tubes intended for hydrogen filling, and in the little coupler through the side hole filled with cotton wool. Care should be taken therefore that the small capillary tube does not become stopped up or that the cotton wool becomes soaked with vaseline, oil and so on.

Calculation of Microphones' Sensitivity.

The calculations are made for a number of frequencies at the lower

end of the frequency range, for example for the frequencies 100, 200, 500, 1000 and 2000 c/s and are set up according to the following scheme:

Microphones Type 4111, Nos. 190 and 191,
Polarization Voltage: 155 volts.
2.96 cm^3 Coupler used.

Frequency c/s	100	200	500	1000	2000	c/s
190 transmitter 191 receiver e_c/e_2	10.4	10.6	11.2	12	14.5	db
191 transmitter 190 receiver e_c/e_2	10.5	10.7	11.2	11.9	14.3	db
Average difference n, e_c/e_2	10.4	10.6	11.2	12.0	14.4	db
Average sensitivity $-50-\frac{n}{2}$	-55.2	-55.3	-55.6	-56.0	-57.2	db re 1 volt/µbar
191 is more sensitive than 190, m	0.4	0.4	0.4	0.3	0.2	db
Absolute sensitivity of No. 191 $-50-\frac{n}{2}+\frac{m}{2}$	-55.0	-55.1	-55.4	-55.9	-57.1	db re 1 volt/µbar
Absolute sensitivity of No. 190 $-50-\frac{n}{2}-\frac{m}{2}$	-55.4	-55.5	-55.8	-56.1	-57.3	db re 1 volt/µbar

The frequency characteristic is taken from the electrostatic actuator measurement, and as a check it should be noted whether the sensitivity calculated at the above selected frequencies corresponds to the frequency characteristic.

If the large ASA coupler is used, the fig. -41.8 should be used instead of -50 when calculating the average sensitivity.

Adjustment of the Calibration Apparatus' Capacity.

As the microphone sensitivity is here defined on the basis of the cathode-follower's output voltage it is important that the microphone cartridge which acts as transmitter with the e_c measurement works with an "output capacity" from the calibration apparatus equal to the input capacity of the cathode-follower.

The cathode follower's input capacity is found by comparing the output voltage when a fixed voltage is led to the input via a

5000 pF capacitor C_S, and when the same voltage is led via a smaller capacitor of approx. 50 pF, C_m, whose exact value must be known. The microphone cartridge itself can be used as a small capacitor. It should be screwed on, insulated from the cathode-follower by means of the insulation ring. To make contact between the cartridge's electrode and the contact pins on the cathode-follower a small extension connector should be inserted, see fig.

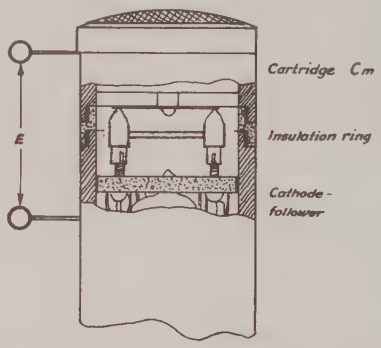


Fig. 15. Details of the insulation ring and coupling contact insertion on the cathode follower.

15. The cartridge's capacity C_m (approx. 50 pF) should be measured in a capacity bridge. If the voltage when C_m is used is e_m and when C_s is used e_s, the input capacity C_f of the cathode-follower with a warm tube is found from

$$\frac{e_m}{e_s} = \frac{C_m}{C_m + C_f}$$

The ratio $\frac{e_m}{e_s}$ is found easily by recording both voltages on the same paper, as shown on fig. 16. In the example measured C_f = 11 pF, and it is important that the calibration apparatus is adjusted in accordance herewith. (Fig. 17). The little trimmer on the diagram marked C_6 is used for this purpose. The trimmer is easily accessible when the back-plate of the calibration apparatus is removed. The adjustment of the trimmer is made as is shown in fig. 17.

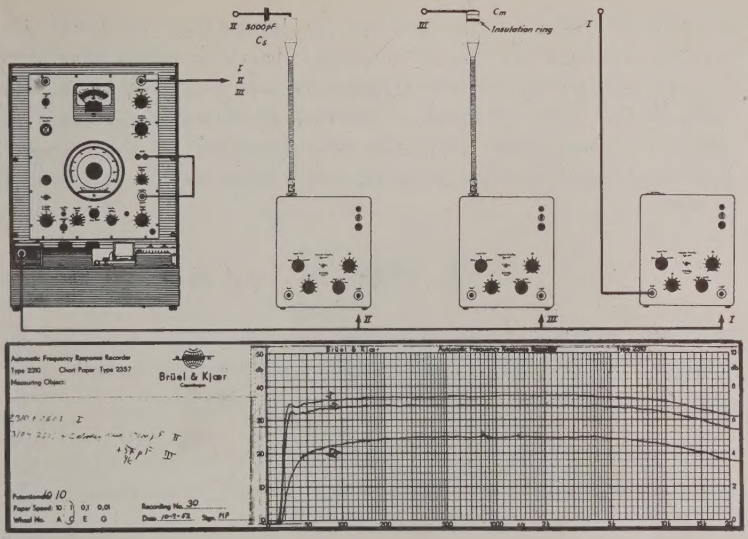


Fig. 16. Measuring a cathode follower's damping effect by comparison of output voltage(curve I) with constant input voltage, and via a 5000 pF capacitor(curve II), which gives the cathode follower's damping effect, and via the microphone cartridge(curve III), which gives the total damping, inclusive of the cathode follower's input capacity. A 10 db potentiometer is used with the curves shown.

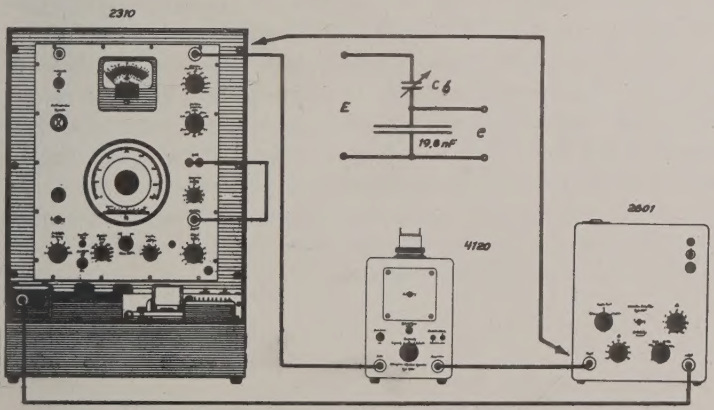


Fig. 17. Adjustment of the Calibration Apparatus' "series capacity"(trimmer in apparatus).

There is no microphone cartridge in the calibration apparatus, and the two contact pins should be connected together with a thin wire. The switch should be placed on "Capacity" and the voltage drop over capacity C_1 = 19800 pF found in relation to the input voltage E in series with the trimmer and distributed capacity. If the cathode-follower's input capacity is 12 pF, the trimmer should be adjusted, so that

$$\frac{E}{e} = \frac{19800}{12} = \text{or} \quad 64.3 \text{ db}$$

By direct coupling of the microphone amplifier to the B.F.O.'s attenuator this damping can be adjusted with great precision. The Level Recorder in 2310 is here used only as indicator.

When a calibration apparatus is delivered from the factory it is adjusted to 12 pF, as all the cathode-followers in microphone 4111 have input capacities between 11 and 13 pF.

Conversion to Open-Circuit Voltage.

If in agreement with ASA standards it is desired to express the microphone cartridge's sensitivity as a ratio between the open-circuit voltage and the sound pressure, the sensitivity found above is corrected merely for the voltage drop in the cathode-follower and for the reduction in sensitivity which takes place because the cathode-follower's input capacity lies above the microphone's capacity. The correction factor is found easiest by screwing an insulating ring between the cartridge and the cathode-follower and comparing the microphone amplifier's output voltage when a fixed voltage is applied across the microphone cartridge with the same voltage applied directly to the microphone amplifier's input. The set-up is seen in fig. 16, together with a typical curve which shows the correction factor directly in db.

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